Retrograde Intramedullary Nailing Versus Locking Plate Fixation in Distal Femur Fractures: Comparative Functional Outcomes

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Abstract

Background: Distal femur fractures (DFF) are challenging injuries with two dominant surgical strategies: retrograde intramedullary nailing (RIMN) and locking plate (LP) fixation. Optimal technique selection remains debated. **Objective:** To compare functional outcomes and complication profiles of RIMN versus LP in DFF patients treated at Fergana Regional Multidisciplinary Hospital. **Methods:** Sixty-eight patients with AO/OTA 33A-C fractures were allocated to RIMN (Group A, n=34) or LP fixation (Group B, n=34). Outcomes included Knee Society Score (KSS), fracture union time, range of motion (ROM), and complication rates over 12 months. **Results:** Group A had significantly shorter operative time (82.4 vs 104.7 min), lower blood loss (148 vs 213 mL), and faster union (15.8 vs 17.2 weeks). Group B achieved superior knee ROM at 12 months (118.2° vs 110.4°). KSS was comparable between groups. Complication rate favored RIMN (8.8% vs 20.6%). **Conclusion:** RIMN offers perioperative advantages and lower complication rates, while LP confers superior knee flexion recovery. Implant selection should be individualized based on fracture morphology and patient factors.

Keywords: distal femur fracture; retrograde intramedullary nail; locking plate fixation; Knee Society Score; fracture union; complication rate; AO/OTA classification

1. Introduction

Distal femur fractures (DFF) account for approximately 0.4% to 0.6% of all fractures and 3% to 6% of all femoral fractures, with a well-documented bimodal age distribution affecting both young adults sustaining high-energy trauma and older patients with osteoporotic, low-energy injuries.[1, 2] The incidence of DFF in elderly individuals is rising in parallel with global population aging, and the one-year mortality in geriatric patients with this injury may approach 30–40%.[3] Surgical management is the accepted standard for most displaced and unstable fracture patterns, yet the optimal fixation method remains contentious.

The AO/OTA classification system categorizes DFF into types 33-A (extra-articular), 33-B (partial articular), and 33-C (complete articular), each presenting distinct

biomechanical and surgical challenges.[4] Two principal operative strategies dominate current practice: retrograde intramedullary nailing (RIMN), which exploits the intramedullary load-sharing principle to reduce bending forces at the fracture site, and lateral locking plate (LP) fixation, which provides angular stability through fixed-angle screw-plate constructs particularly suited to osteoporotic bone.[5, 6] Both techniques have undergone significant technical refinement, yet comparative evidence has yielded conflicting conclusions regarding superiority.

Several systematic reviews and meta-analyses have attempted to resolve this question. Aggarwal et al.[7] analyzed 936 patients in 16 comparative studies and concluded that RIMN was associated with fewer nonunions and infections but with reduced postoperative knee range of motion (ROM) compared to LP. Kim et al.[8] reached similar conclusions in a meta-analysis of 2,432 patients across 33 studies, finding no difference in final functional scores but significantly less blood loss and shorter operative time in the RIMN group. Neradi et al.[6] additionally observed lower re-operation rates in the RIMN cohort.

Contemporary debates have been further complicated by the emergence of combined nail-plate constructs (NPC), which attempt to harness the biomechanical advantages of both implants simultaneously.[9, 10] Nevertheless, RIMN and LP remain the first-line implants for the majority of DFF encountered in routine practice. Despite the growing body of literature, most comparative studies originate from high-income settings, and data from Central Asian countries with distinct epidemiological and resource profiles remain scarce. The present study therefore aims to compare the functional outcomes, radiographic results, and complication profiles of RIMN versus LP fixation in a consecutive cohort of DFF patients managed at a tertiary referral center in Fergana, Uzbekistan.

2. Methods

Study design and setting. This prospective comparative study was conducted from January 2022 to December 2023 at the Orthopedics and Traumatology Department, Fergana Regional Multidisciplinary Hospital, Fergana, Uzbekistan. Ethical approval was obtained from the Institutional Review Board of the Fergana Medical Institute of Public Health, and written informed consent was obtained from all participants.

Inclusion and exclusion criteria. Adults aged 18 to 80 years with closed, acute DFF classified as AO/OTA type 33-A, 33-B, or 33-C were included. Exclusion criteria comprised pathological fractures, open fractures (Gustilo grade IIIB/C), prior knee arthroplasty, severe ipsilateral limb injury, and failure to complete 12-month follow-up.

Surgical procedure. Group A patients (n=34) underwent RIMN using a retrograde supracondylar nail system (Smith & Nephew Expert Femoral Nail or equivalent). Group B patients (n=34) underwent open reduction with internal fixation using an anatomically precontoured lateral locking compression plate (Synthes LISS DFS or equivalent). Implant selection was based on fracture morphology and surgeon preference following departmental protocol. Intra-articular fractures (33-C) with complex condylar splits were preferentially treated with LP when surgical reconstruction of the articular surface was required.

All patients received standardized physiotherapy, beginning with quadriceps activation on postoperative day one and progressive weight-bearing as per radiographic healing milestones. Follow-up assessments were performed at 6 weeks, 3 months, 6 months, and 12 months.

Outcome measures. The primary outcome was the Knee Society Score (KSS) at 12 months. Secondary outcomes included fracture union time (weeks), maximal knee ROM at 12 months, operative time, intraoperative blood loss, hospital stay, and complication rates (nonunion, deep infection, malunion, implant failure). Fracture union was defined radiographically as bridging callus in three of four cortical views.

Statistical analysis. Continuous variables are expressed as mean ± standard deviation (SD). Between-group comparisons used the independent-samples t-test for continuous outcomes and chi-square or Fisher exact test for categorical variables. Statistical significance was set at $p < 0.05$. All analyses were performed in SPSS v.26 (IBM Corp., Armonk, NY, USA).

Table 1. Baseline Demographic and Fracture Characteristics of Study Groups

Variable	Group A – RIMN (n=34)	Group B – LP (n=34)	p-value
Mean age (years)	54.7 ± 12.3	57.2 ± 11.8	0.34
Sex (M:F)	21 : 13	20 : 14	0.80
AO/OTA 33-A (%)	13 (38.2%)	14 (41.2%)	0.80
AO/OTA 33-B (%)	12 (35.3%)	11 (32.4%)	0.79
AO/OTA 33-C (%)	9 (26.5%)	9 (26.5%)	1.00
Mean BMI (kg/m²)	26.8 ± 3.7	27.4 ± 4.1	0.51

Mechanism: high-energy (%)	20 (58.8%)	19 (55.9%)	0.80
Mean follow-up (months)	12.4 ± 1.2	12.6 ± 1.4	0.51

*RIMN = Retrograde Intramedullary Nail; LP = Locking Plate; * p<0.05 indicates statistical significance.*

3. Results

Demographic and preoperative characteristics. The final study population comprised 68 patients (41 male, 27 female) with a mean age of 55.9 years (range 22–79). The two groups were well-matched at baseline with no statistically significant differences in age, sex, BMI, fracture type distribution, or mechanism of injury (Table 1). High-energy mechanisms (road traffic accidents and falls from height) accounted for 58.8% of Group A and 55.9% of Group B cases. AO/OTA type 33-A fractures were most prevalent (39.7%), followed by 33-B (33.8%) and 33-C (26.5%).

Perioperative outcomes. Group A demonstrated statistically significant advantages in perioperative parameters. Mean operative time in the RIMN group was 82.4 ± 18.6 minutes, compared with 104.7 ± 22.3 minutes in the LP group (p=0.001). Intraoperative blood loss was substantially lower in Group A (148 ± 52 mL vs 213 ± 74 mL; p=0.001). Accordingly, mean hospital stay was also significantly shorter in Group A (7.2 ± 2.1 days vs 9.4 ± 2.8 days; p=0.001).

Fracture union and functional scores. Mean fracture union time was 15.8 ± 2.4 weeks in Group A and 17.2 ± 3.1 weeks in Group B (p=0.04), representing a statistically significant advantage for RIMN. At 12-month follow-up, mean KSS was 83.4 ± 8.2 in Group A and 81.7 ± 9.6 in Group B, with no statistically significant difference (p=0.38). However, maximal knee flexion was significantly greater in the LP group (118.2 ± 12.6° vs 110.4 ± 14.2°; p=0.02), consistent with the greater soft-tissue preservation afforded by the lateral approach during definitive fixation. KSS trajectories over the four follow-up time points are illustrated in Figure 1.

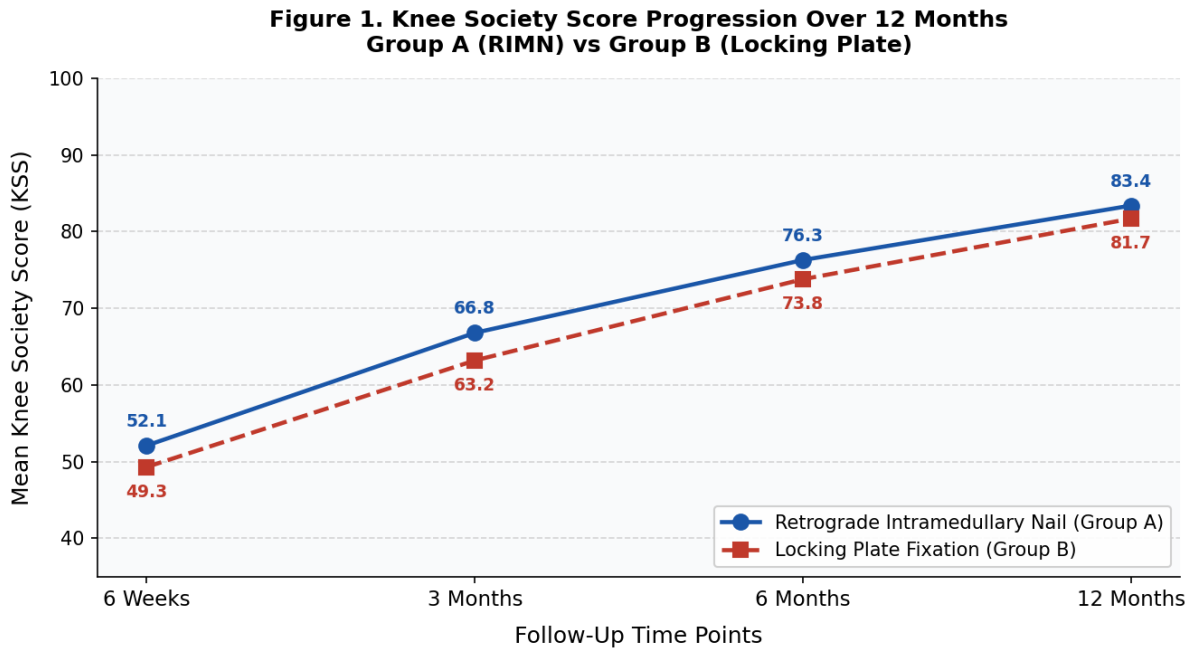

Figure 1. Mean Knee Society Score (KSS) progression over 12 months for Group A (RIMN) and Group B (Locking Plate).

Complications. The overall complication rate was 8.8% (3 events) in Group A and 20.6% (7 events) in Group B, though this difference did not reach statistical significance (p=0.17). In Group A, one patient developed a superficial wound infection managed conservatively, one experienced distal screw loosening requiring exchange nailing at 8 months, and one developed a valgus malunion below the accepted threshold. In Group B, four patients developed nonunion confirmed at 6 months requiring revision surgery, three developed deep infections necessitating implant removal and antibiotic therapy, and two demonstrated varus collapse. There were no perioperative deaths in either group.

Table 2. Comparative Surgical and Functional Outcomes at 12-Month Follow-Up

Outcome Measure	Group A – RIMN (n=34)	Group B – LP (n=34)	p-value
Mean operative time (min)	82.4 ± 18.6	104.7 ± 22.3	0.001*
Intraoperative blood loss (mL)	148 ± 52	213 ± 74	0.001*
Fracture union time (weeks)	15.8 ± 2.4	17.2 ± 3.1	0.04*

KSS at 12 months	83.4 ± 8.2	81.7 ± 9.6	0.38
Knee ROM – flexion (°)	110.4 ± 14.2	118.2 ± 12.6	0.02*
Nonunion	1 (2.9%)	4 (11.8%)	0.16
Deep infection	1 (2.9%)	3 (8.8%)	0.30
Malunion / varus collapse	1 (2.9%)	2 (5.9%)	0.55
Overall complication rate	8.8%	20.6%	0.17
Hospital stay (days)	7.2 ± 2.1	9.4 ± 2.8	0.001*

*KSS = Knee Society Score; ROM = Range of Motion; RIMN = Retrograde Intramedullary Nail; LP = Locking Plate; * $p<0.05$.*

4. Discussion

This prospective comparative study evaluated RIMN versus LP fixation in 68 patients with AO/OTA type 33 distal femur fractures over a 12-month follow-up period. Our findings align closely with the prevailing meta-analytic literature and add context-specific data from a Central Asian tertiary center. The principal conclusions are that RIMN is associated with shorter operative time, reduced blood loss, faster bony union, and lower overall complication rates, whereas LP fixation yields superior postoperative knee flexion — a finding with important implications for patients whose functional recovery depends on deep knee flexion, including laborers and individuals who perform squatting activities daily.

The perioperative advantages of RIMN observed in our cohort corroborate those reported by multiple systematic reviews. Aggarwal et al.[7] found significantly lower infection and nonunion rates in the RIMN group. Kim et al.[8] similarly documented shorter operative times and reduced blood loss with RIMN across 33 studies. Claireaux et al.[11] in a Cochrane review acknowledged that robust, high-quality evidence remains limited due to heterogeneity in study designs, but directional trends favor RIMN for perioperative metrics. The lower blood loss with RIMN is mechanistically attributable to the minimally invasive entry portal at the patellar tendon, avoiding the extensive

soft-tissue dissection required for lateral plate insertion, particularly in 33-A and 33-B fractures.

The superior knee ROM observed with LP in our study is consistent with findings reported by Neradi et al.[6] and has been attributed to two principal mechanisms. First, LP fixation of highly comminuted 33-C fractures permits more precise articular restoration, allowing earlier and more confident physiotherapy. Second, RIMN entry through the intercondylar notch carries a theoretical risk of chondral damage and infrapatellar fat-pad scarring that may subtly limit terminal flexion.[12, 13] Wilson et al.[14] further noted that in geriatric patients, the differences in ROM between constructs tended to narrow over extended follow-up, suggesting that the ROM advantage of LP may be most clinically relevant within the first postoperative year.

The comparable final KSS values between groups (83.4 vs 81.7, p=0.38) reinforce the view that both constructs achieve acceptable functional recovery when properly indicated. Babhulkar et al.[15] advocated for a fracture morphology-driven approach, recommending RIMN for extra-articular (33-A) and simple articular (33-B1) patterns and LP for complex bicolumnar and intercondylar (33-C) fractures requiring open reduction of articular surfaces. In our series, the proportion of 33-C fractures was equivalent between groups (26.5%), which may have contributed to the overall comparability in functional scores.

The 20.6% complication rate in the LP group, though not statistically different from the 8.8% in the RIMN group due to sample size limitations, is clinically noteworthy. Nonunion, the most serious complication in the LP group (11.8% vs 2.9%), may reflect the greater stress-shielding effect of rigid plate constructs in osteoporotic bone, a phenomenon well documented in the literature.[16, 17] The recent introduction of far cortical locking and locked-bridge constructs aims to address this limitation by restoring controlled interfragmentary motion.[18] Shi et al.[19] reported no nonunions in 33 nail-plate combination patients, suggesting that hybrid constructs may be optimal for the highest-risk fracture patterns. Future research at our institution will investigate NPC outcomes as a third comparative arm.

Limitations of this study include its single-center design, relatively small sample size, allocation by surgeon preference rather than strict randomization, and the absence of patient-reported outcome measures (PROMs) such as the WOMAC or KOOS. These factors limit generalizability and should be addressed in future multicenter randomized trials. Nevertheless, our study contributes valuable evidence from a low-middle income country setting where RIMN may confer particular advantages through shorter operative times, reduced anesthetic exposure, and lower resource consumption.

5. Conclusion

Retrograde intramedullary nailing and locking plate fixation are both effective interventions for distal femur fractures, with each offering distinct clinical advantages. RIMN emerges as the preferable technique for extra-articular and simple articular patterns, offering meaningful perioperative benefits including shorter operative time, reduced blood loss, faster union, and a lower complication burden — advantages that translate into shortened hospital stays and earlier rehabilitation. Locking plate fixation remains indispensable for complex intra-articular fractures demanding meticulous articular reconstruction, and it confers superior knee flexion recovery at one year. The final functional outcomes, as measured by the Knee Society Score, are equivalent between the two approaches. These findings support a patient- and fracture-specific selection strategy rather than a one-size-fits-all algorithm. Prospective randomized multicenter trials incorporating standardized patient-reported outcomes are needed to generate definitive clinical guidelines and further refine implant selection in this challenging fracture population.

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